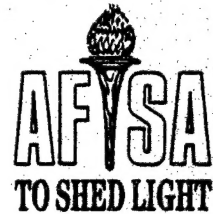


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**Air Force Center
for
Studies & Analyses**



**C-17
CONTAINER
STUDY**

**STUDY DIRECTOR:
CARL D. SULLIVAN**

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STUDY REPORT

JANUARY 1987

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 **STUDY REPORT** 

JANUARY 1987

FOREWORD

An analysis of the operational impacts of loading eight versus six containers in the C-17 was conducted at the request of AF/RDQL by the members of the Mobility Division, Directorate of Theater Force Analyses, Air Force Center for Studies and Analyses.

Study results were briefed to AF/SA in Nov 86 and to the Joint Resource Management Board (JRMB) in Nov 86. In addition, an Executive Summary of findings was provided to AF/RDQL in Nov 86.

The following participated in the study: Mr Carl D. Sullivan was Study Director; study guidance and collateral analytical support were provided by Maj Michael E. Strickland, Maj Charles D. Dillard, Col Robert P. Keighery, and Col William J. Haugen; Mrs Sheila M. Head and Ms Tonja L. Bolden provided outstanding secretarial support.

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EXECUTIVE REPORT

C-17 CONTAINER REQUIREMENT STUDY EXECUTIVE REPORT

INTRODUCTION

In their letter of 28 March 1986, AF/RDQL asked for AF/SAGM assistance in assessing the changes in closure resulting from loading eight containers on the C-17. The following is an assessment of the impact on closure of alternative eight versus six container C-17 configurations.

SCOPE:

1. The analysis was limited to assessing the impact on closure times of alternative container handling configurations for C-17 operations alone.
2. We confined our study to the question of impact on closure from movement of eight versus six containers on the C-17, although availability of containers, pallets, and handling equipment may have a greater impact on timely deployment.
3. Only existing container or pallet loading options and the two eight-container options determined feasible by AFCSA/ASD were considered
 - a. The capability of the C-17 to handle eighteen 463L pallets was used as a baseline for comparing container handling options.
 - b. With the applicable number of tie down points on the ramp, the C-17 can handle six containers on pallets in the aircraft rail system. Eight containers could be handled on the same system.
 - c. With modification of the aircraft rail system, and use of a special tie-down kit, eight containers or tactical shelters could be loaded directly into the aircraft, reducing tare weight. We refer to this option as the "integral option."

ASSUMPTIONS:

1. Containers or pallets and their handling equipment would be required for deploying units.
2. All bulk cargo not meant to be moved on a unit's own vehicles would be palletized or containerized, as applicable.
3. As was done in the Transportation Systems Center (TSC) study, we accepted the findings of previous studies that loading efficiency would approximate 68% maximum cube utilization for pallets and 75% for containers.
4. Tare (empty) weights are 354 pounds for each 463L pallet, and 4,770 pounds for each container.

5. An operational load for the C-17 is 18 pallets, 6 containers, or 8 containers. Maximum allowable cabin load (ACL) is 172,200 pounds.
6. The C-17 will retain the capability for centerline loading of four containers, and this has no impact on other loading options.
7. Ground handling time for these configurations will not affect closure time.
8. Marine units were assumed to be similar to Army units.

METHODOLOGY:

1. We determined airlift requirements for the FY92 timeframe using the data base developed by TSC as a source for representative Air Force and Army units (divisions, brigades, squadrons, etc.) to be deployed.
2. The Army Tables of Organization and Equipment (TOE) and Air Force Logistics Detail and Logistics Summary (LOGDET and LOGSUM) files which reflect manpower and equipment assigned to those units were updated to include the future distribution of tactical shelters, as projected by the TSC study.
3. The Airlift Loading Model (ALM) was used to develop sortie requirements and average payloads. The ALM simulates loading of unit equipment and accompanying supplies on specified aircraft. The model considers aircraft cargo compartment dimensions and ACL, vehicle dimensions and weights, and the number of pallets and containers allowable on the aircraft. In deployments of the size envisioned in this study, where a large number of sorties are required, closure time is proportional to the number of sorties involved.
4. Four potential C-17 loading options were assessed:
 - a. The use of eighteen 463L pallets was established as the baseline.
 - b. The aircraft was configured to carry six containers on pallets.
 - c. The aircraft was configured to carry eight containers on pallets.
 - d. The aircraft was configured to carry eight containers in the integral option rail system, without pallets.
5. There were no mixed loads of pallets and containers.

FINDINGS

1. Previous studies conducted by both DOD and industry show that in 90 to 95% of airlifted containers, net cargo weights will range between 8,000 and 17,000 pounds per container. Within these parameters we found that:

a. The lighter the average container load, the larger the difference in closure time between six- and eight-container configurations.

b. The 6-container loading option always requires more sorties and closure time than 8 containers or 18 pallets.

c. A closure reduction between 0 and 8% occurred when the C-17 carried eight containers, rather than six, depending on the extent that a deploying unit's equipment can be containerized. The reduction when deploying an airborne division was 8 percent. The average reduction for units expected to be deployed by air was 4 percent.

d. A closure reduction of 0 to 2% occurred when the C-17 carried 8 containers rather than 18 pallets. This applied to both 8-container options.

e. For comparison, a 10% reduction in closure represents less than 1-day savings for a typical 5-day deployment to a theater of approximately 5,000 miles distance.

2. While some units (army air assault, airborne, combat service support) have the possible requirement to move up to 1,000 or more containers, there is little to be gained from containerizing many other units because they have a limited amount of bulk cargo to be containerized. Armored, infantry, and mechanized infantry units move most of their bulk cargo on their own vehicles, so containerization is not required.

EXTENDED ANALYSIS

EXTENDED ANALYSIS BACKGROUND

Some specific tasks were included in the Secretary of Defense Decision Memorandum (SDDM) of 15 Feb 85 which authorized the Full Scale Engineering Development (FSED) of the C-17. OSD was directed to determine the portion of the wartime unit equipment and resupply loads likely to be containerized in the year 2000. The Air Force was directed to determine the most effective way for the C-17 to carry eight 20 foot containers in a wartime mobilization scenario. The former resulted in a study, "Estimate of the Wartime Container Movement Requirements By Air In The Year 2000," accomplished by the Department of Transportation, Transportation Systems Center (TSC). USAF tasked the Air Force Systems Command (AFSC) with determining the most effective way to carry 8 commercial containers (8 feet x 8 feet x 20 feet) on the C-17. Air Force Center For Studies and Analyses (AFCSA/SA) examined the impact on closure time of 6- and 8-container C-17 configurations.

This study was begun in March 86 in response to a request from AF/RDQL. The objective of this study was to analyze the change in unit closure time which would result from increasing the C-17 container capacity from six to eight containers. The aircraft is configured to carry eighteen 463L pallets. This was used as the baseline. Aircraft configurations which would accommodate six containers and/or eight containers were compared to the baseline.

Also addressed were other factors which became apparent during the study and found to be pertinent to airlifting containers, as well as tactical shelters.

ANALYTICAL APPROACH

The measure of effectiveness of the study is the percentage of change in closure time relative to palletization for the three optional configurations for container loading on the C-17.

The analysis was limited to assessing the impact of alternative container handling configurations for C-17 operations alone. Consideration of the entire airlift fleet as envisioned in the Airlift Master Plan (AMP) would have masked the potential impact of the C-17 configurations on closure. The C-17 is expected to be the primary cargo aircraft by the year 2000 and variations in its capacity could impact on timely deployment of forces. The study concentrated on the movement of airland containers which approximate the 8x8x20 foot size governed by the International Organization For Standardization, (commonly called ISO containers). Tactical shelters being procured by the Services are basically the same size as ISO containers.

For purposes of the study, an operational load for the C-17 was considered to be 18 pallets, 6 containers, or 8 containers. Maximum allowable cabin load (ACL) for palletized and containerized configurations is 172,200 pounds. The C-17 is currently designed with the additional capability for centerline loading of four containers. This capability is most applicable to combat offload operations and has no impact on other loading options. Only existing pallet loading options and the six- and eight-container options determined feasible by the AFSC/ASD "C-17 Eight Commercial Container Study" were considered in this study.

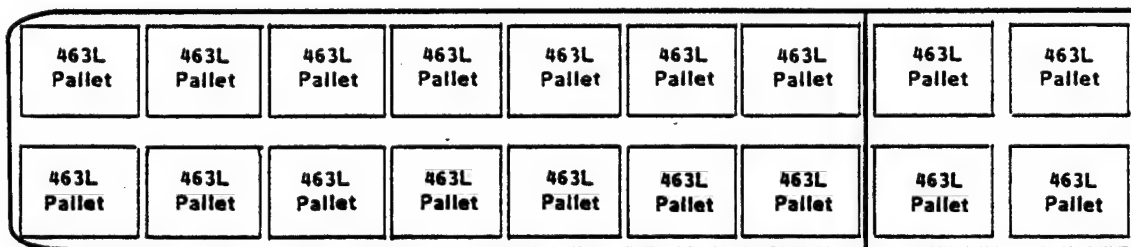


Figure 1. EIGHTEEN PALLET LOAD CONFIGURATION

The capability of the C-17 to handle eighteen 463L pallets was used as a baseline for comparing container handling options (Figure 1).

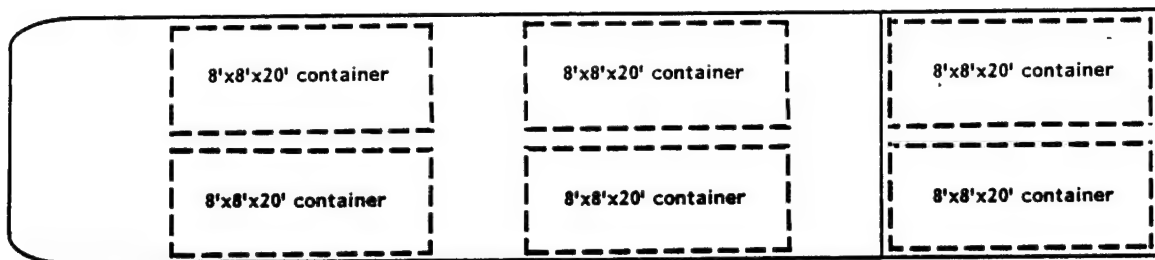


Figure 2. SIX CONTAINER LOAD CONFIGURATION

The C-17 is presently designed to handle six containers on pallets in the 88 inch aircraft rail system (Figure 2). This requires containers to be loaded on either 463L married pallets with wooden shoring beneath the container, or on adapter pallets, and secured to the floor of the aircraft. Six containers can be secured with the use of cross-chains which provide adequate restraint fore and aft, however four additional tie-down rings are required on the ramp.

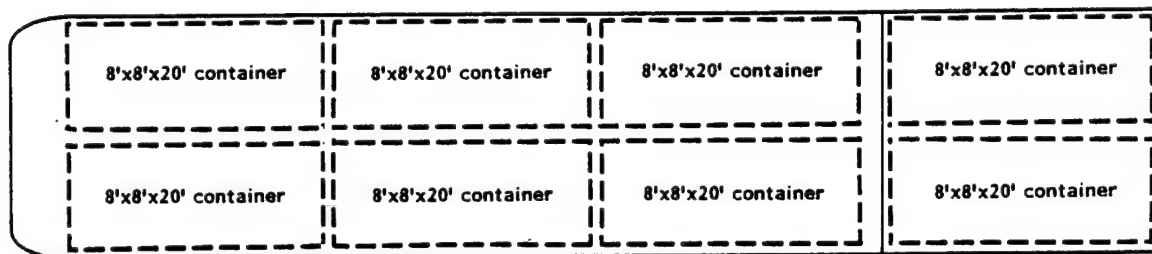


Figure 3. EIGHT CONTAINER LOAD CONFIGURATIONS

The AFSC/ASD effort found there were two feasible methods to carry eight containers in the C-17 (Figure 3). Eight containers can be loaded into the existing rail system on pallets and secured with a specially designed tie-down system. With modification of the aircraft rail system, and use of special tie-down kit, eight flat-bottomed containers or tactical shelters could be loaded directly into the aircraft. We refer to the latter option as the "integral option". Currently, less than 10% of containers and tactical shelters available for movement have flat bottoms which would be compatible with this option.

For analysis purposes, containers were not mixed with pallets on the aircraft loads simulated during the study. It is probable that mixed loads of containers, shelters, pallets and rolling stock will occur during actual deployment. However, because of the potential for large numbers of containers and tactical shelters in the units, it is not unrealistic to consider that pure container/shelter loads would occur. It was also assumed that all bulk cargo not planned to be moved on a unit's own vehicles would be palletized or that loading efficiency would approximate 68% maximum cube utilization for pallets and 75% for containers. Tare (empty) weights are 354 pounds for 463L pallets and 4,770 pounds for containers. An adapter pallet designed to handle the containers will weigh approximately 1,600 pounds;

We determined airlift requirements for the FY92 time frame using the data base developed for the "Estimate of The Wartime Container Movement Requirements By The Year 2000" study performed by the Transportation Systems Center (TSC).

After a review of the TSC study results, representative Air Force units (e.g., fighter and bomber squadrons; and intelligence, security, communication, airlift, PRIME BEEF, support, and medical units) and Army units (e.g., light infantry divisions, cavalry brigade air combat, and combat service and combat support units) were selected for this study. Army units were grouped according to size and cargo characteristics for ease in analysis. Air Force units were combined and addressed as a single entity.

The Army Table of Organization and Equipment (TOE) and Air Force Logistics Detail and Logistics Summary (LOGET and LOGSUM) files which reflect manpower and equipment assigned to those units selected were updated to include the future distribution of tactical shelters, as projected by the TSC study. (Because of their similarity to Army units being considered, Marine units were not addressed separately).

EXAMINATION OF THE ISSUE

Previous studies conducted by both DOD and industry show that in 90 to 95% of airlifted containers, net cargo weights will range between 8,000 and 17,000 pounds. No more than 2 to 3% of containers will carry cargo with less density than this range, because such cargo is very rare. For example, a container full of ping pong balls would approximate 6,000 pounds. By the same token, very few containers will exceed this range, because the weight will approach the 25,000 pound maximum allowable gross weight for airlift containers. A bulk density which would yield an average net container weight for airlift of 12,500 pounds was considered most probable in this study.

The Airlift Loading Model (ALM) was used to develop sortie requirements and average payloads. The ALM simulates loading of unit equipment and accompanying supplies on specified types of aircraft. The mode considers aircraft cargo compartment dimensions and allowable cabin load (ACL); vehicle dimensions and weights; and the number of pallets and containers which can be loaded on the aircraft.

C-17 CONTAINER ANALYSIS Representative Deployments (Containerization Closure Reduction Relative to Palletization)

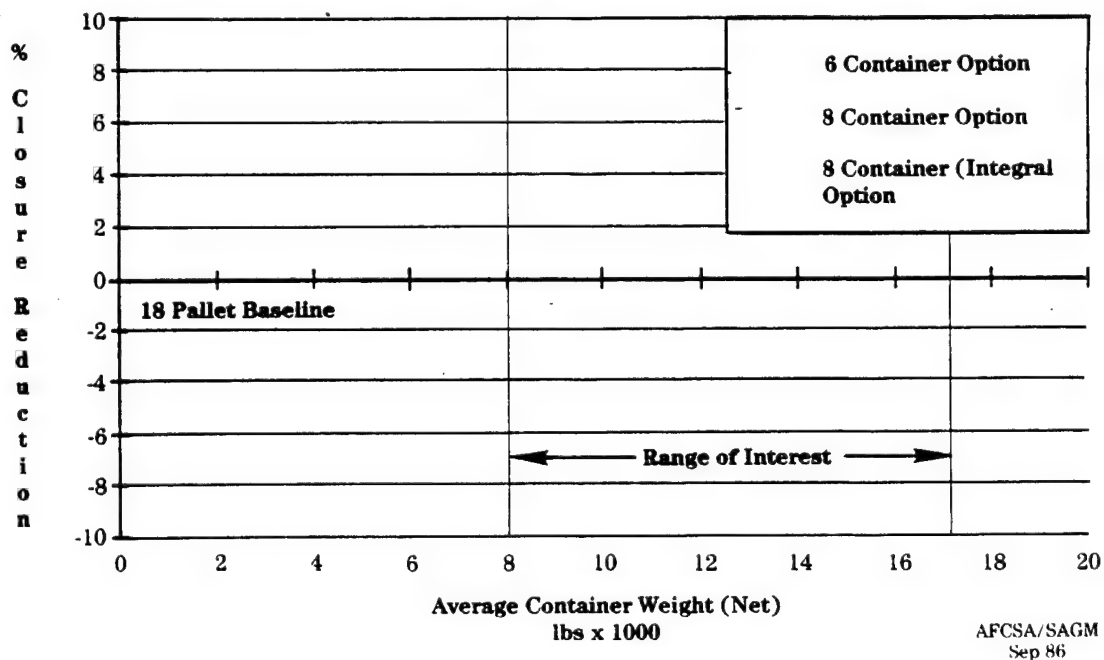


Figure 4. THE BASIC GRAPH FORMAT

The change in closure time relative to the time required when the 18 pallet baseline is carried, was calculated for a range of average container weights. This can be depicted graphically as in Figure 4. Percentages on the Y axis reflect improvement or degradation of closure. Average net container weights are on the X axis. The "Range of Interest" is that area where studies show 90 to 95% of net container loads will occur. The horizontal center line represents the 18-pallet configuration that is used as a baseline. Movement of six containers, and the two eight-container options, will be depicted by lines on the chart.

C-17 CONTAINER ANALYSIS

Air Force Deployments

(Containerization Closure Reduction Relative to Palletization)

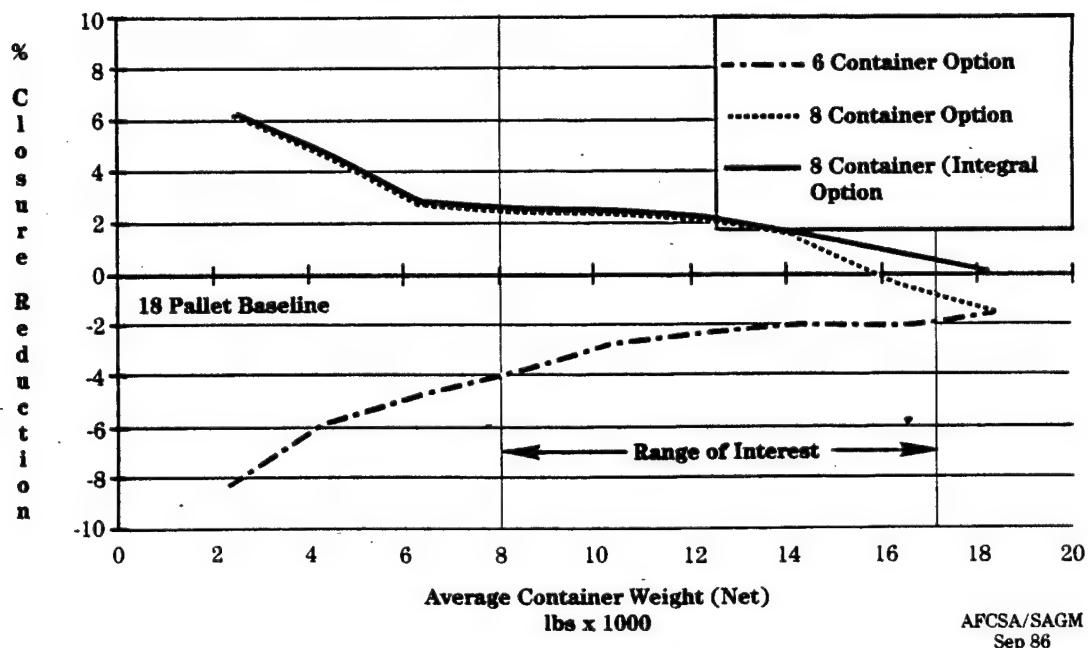


Figure 5. POTENTIAL CLOSURE REDUCTION FOR AIR FORCE UNITS

The graph in Figure 5 shows Air Force units, including the support forces, grouped as a single deployment. Sortie requirements would be similar to those required to move Army light divisions. While the graph reflects a potential 6% reduction in closure if net container loads are in the 8,000 pound range when 8 containers rather than 6 are moved, only a 2% reduction exists when 8 containers rather than 18 pallets are moved. Both areas of potential closure reduction rapidly deteriorate as cargo densities increase. At net loads exceeding 14,000 pounds, the difference in tare weight of the 8 container options becomes apparent. In the integral configuration, only the 4,700 pound tare weight of the container is considered, while 6,300 pounds of tare weight exist if containers are loaded on 463L pallets. At this point, however, gross container weights begin to approach the maximum of 25,000 pounds. The allowable cabin load for the C-17 is 172,200 pounds, thus no more than 6.8 containers with gross weights of 25,000 pounds could be loaded. In other words, it is not possible to load the aircraft to handle eight containers at maximum gross weight.

The type of unit being deployed has considerable effect on the applicability of containerization. The necessity to move containers and/or shelters in large numbers should certainly be considered in assigning types of aircraft to the mission.

C-17 CONTAINER ANALYSIS Army Light Division Deployments (Containerization Closure Reduction Relative to Palletization)

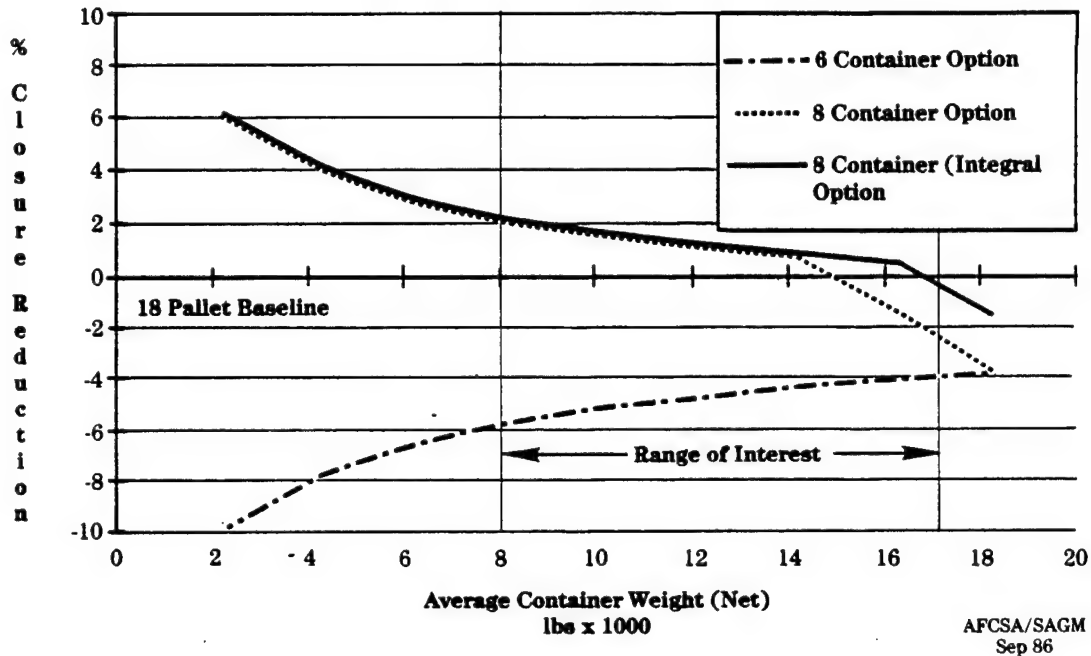


Figure 6. POTENTIAL CLOSURE REDUCTION FOR ARMY LIGHT DIVISIONS

The Army light infantry division (LID), air assault division, cavalry brigade air combat (CBAC), and airborne division share the same bulk and equipment characteristics. The density of the bulk cargo to be moved, however, is higher than that of Air Force units. We find 8 container movement gives up to 8% better closure time than 6 container movement, and less than 2% is to be gained through movement of 8 containers instead of 18 pallets (Figure 6).

C-17 CONTAINER ANALYSIS **Army Corps Support Deployments** (Containerization Closure Reduction Relative to Palletization)

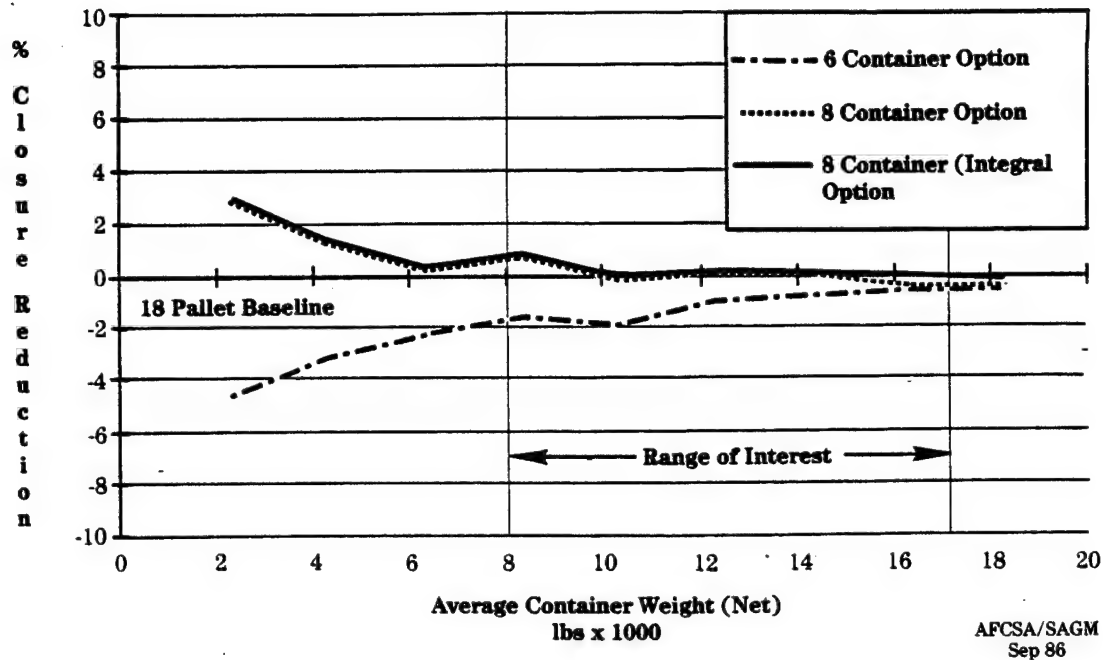


Figure 7. POTENTIAL CLOSURE REDUCTION FOR ARMY SUPPORT UNITS

Medium weight Army units, such as combat support and combat service support, have even less bulk cargo which lends itself to containerization or palletization (Figure 7). As a result, the decision to use containers or pallets for the remaining bulk cargo is of less importance.

Because the heavy Army divisions (armored, infantry, and mechanized infantry) move most of their bulk cargo on their own vehicles, little bulk cargo remains and containerization is not beneficial.

Together, the preceding charts show the following:

A. The 6-container loading option always requires more sorties than the 18-pallet option. Tare (empty) weight of 6 airlift containers on adapter pallets (38,220 pounds) compared to tare weight of eighteen 463L pallets (6,372 pounds) can mean a net reduction of 31,848 pounds cargo moved per sortie

B. A potential closure reduction of 0 to 6% exists when the C-17 carries 8 containers, rather than 6, with average net cargo of 12,500 pounds each.

C. A potential closure reduction of only 1 to 2% occurs when the C-17 carries eight (12,500 pound) containers rather than 18 pallets loaded with cargo of the same density. In this case, the higher cube utilization experienced with containers (75%) compared to the stacking proficiency on pallets (67%); results in more efficient loads. This applies with either of the 8-container options.

D. While some units (Army air assault, airborne, combat service support) have enough bulk to stuff (load) up to 1,000 or more containers, there is little to be gained from containerizing many other units because of the limited amount of bulk cargo they move. Armored, infantry, and mechanized infantry units move most of their bulk cargo on their own vehicles, so containerization is not beneficial.

E. There is no difference in closure for deployment of an armored division regardless of whether its bulk material is moved on pallets or in containers. However, approximately 8% fewer sorties would be required to move an airborne division if its bulk cargo is containerized and moved in aircraft loads of 8 vs 6.

F. If units (e.g., medical, communication) with large numbers of containers or tactical shelters are to be moved, the 8-container C-17 configurations are preferred over the 6-container configuration. The need to deliver tactical shelters or containers may increase the benefits of having a C-17 configured to handle eight containers or shelters.

G. Delivery of cargo over varying distances was tested during the study. A 10% reduction in closure means less than one day savings for deployment to a theater of approximately 5,000 miles distance. In deployments examined in this study, savings due to movement of 8 vs 6 containers ranged from zero to less than half a day.

OTHER FACTORS TO CONSIDER

During the course of the study, other factors surfaced which were outside the parameters of the study, but which may be more pertinent to the subject of containerization during deployment than whether the C-17 is configured to carry six or eight containers. Those which seemed most important were:

A. *Availability of Containers For Deployment:* Timely availability of containers and applicable container handling equipment at points where units assemble their material for deployment should be a major concern for planners. The items which will accompany an air assault or airborne division could conceivably fill up to 1,000 airlift containers. Units with large amounts of equipment will require considerable time to load material into the containers. Unless a sufficient number of airland containers can be physically located within the unit on a day-to-day basis, the lead time required to acquire containers from commercial or military storage sites, added to loading (stuffing) time, could easily degrade the response time of the unit.

B. *Handling Equipment:* Our capability to deploy units in a timely manner may depend on our capability to handle ISO type containers and tactical shelters in the airlift and ground transportation environment. Many types of units (e.g., medical units, engineering units, Navy construction battalion, tactical fighter units) are scheduled to receive large numbers of tactical shelters prior to the year 2000. Special handling equipment will be required, except at those installations where the capability exists to transfer containers onto or off the rollerized materials handling systems, aircraft leading devices, and aircraft rail system. Acquisition of new materials handling equipment requires up to 5 years advance programming. There is insufficient container and shelter handling equipment in place at required locations today, and projected buys may not fill the void. Failure to acquire needed handling equipment may result in airlift being constrained because handling capability is limited.

C. *Arrival Point Congestion:* Availability of container handling equipment and storage space at offload points is also critical. Ground transport functions must have the ability to handle containerized cargo once delivered, especially where prompt movement of containers away from the airfield is important. Congestion in the delivery zone will be compounded by the containers. Some commanders have expressed concern that the large containers also will create an excellent target.

D. *Return of Empty Containers:* Disposition of empty containers may also pose a problem. Retrograde movement of containers will absorb airlift at a much higher rate than will 463L pallets. Pallets may be stacked and moved in aircraft loads into almost any airlift departure point for future use. Containers use as much space in the aircraft while empty as when they are full — they cannot be stacked. The location to which they are returned must have a valid use for containers or their presence only complicates processing and congests the area. Aircraft used for deployment will not necessarily be available for retrograde movement of containers. Transportation of repairable assets and malpositioned cargo, as well as personnel and casualties being removed from the forward areas already provide a challenge to the airlift fleet. An additional requirement to return empty containers to specific CONUS locations may be more than the systems can easily absorb.

E. *Operational/Logistics Benefits*: Any benefits in cargo processing or logistics which have been anticipated through use of containers rather than pallets would not be enhanced by decreased delivery time. For very dense cargo, the additional tare weight of containers actually means less cargo moved per sortie, thus a later closure. There may be some benefits from less handling of individual items (due to consolidation in containers), increased security of items in containers (vice being on 463L pallets), protection from weather factors, and consolidation of each unit's equipment into a single container. However, the potential problems of handling the containers at both onload and offload points could limit benefits in the operational and logistical area.

CONCLUSION

For those units where bulk cargo is available to fill containers, movement of 8 containers versus 6 on the C-17 produces a potential of up to 8% closure reduction. However, at an average net weight of 12,500 pounds per container, the 8 container configuration reduces closure by less than 2% over an 18-pallet configuration.

APPENDIX

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